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TRITIATED D20 TRANSPORT CONTAINER COMPUTER MODEL VERIFICATION PUNCH TEST NO. 1

Report No. 84-338-K

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Technologist
Applied Structural and Solid
Mechanics Section
Mechanical Research Department

ABSTRACT

A program has been undertaken to experimentally test the performance of a proposed transport package for tritiated heavy water. The test to which the model was subjected, simulated the IAEA specified drop test onto a pin except that the weight was approximately 60% of the scaled weight of the proposed cask design, and the drop height was approximately 23% higher. The energy at impact corresponded to about 66% of that calculated for a true 1/4 scale - 1 m drop and the model was found to be very effective in absorbing this amount of energy without failure. This report describes the tests and discusses the results.

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740621-141-461	825.113	January 21, 1985	84-338-K

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EXECUTIVE SUMMARY

TRITIATED D2O TRANSPORT CONTAINER COMPUTER MODEL VERIFICATION PUNCH TEST NO 1

J.H. Russell
Applied Structural and Solid Mechanics Section
Mechanical Research Department

A program aimed at experimentally testing the performance of a preliminary design of a tritiated heavy water transport container, has been undertaken. The container consists of a thin stainless steel shell filled with high density isocyanate foam.

A model, which simulated the base of the proposed container was subjected to an impact test. The test simulated the IAEA specified 1 m drop onto a pin except that the weight was approximately 60% of the scaled weight of the proposed cask design, and the drop height was 1.2 m. The model was found to absorb energy without shearing of the outer shell. The amount of energy corresponded to about 66% of that calculated for a true 1/4 scale - 1 m drop test. This report describes the test and discusses the results.

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TABLE OF CONTENTS

	Page
1.0 INTRODUCTION	1
2.0 PURPOSE	1
3.0 MODEL	1
4.0 INSTRUMENTS AND MEASUREMENTS	2
5.0 TESTS	3
6.0 RESULTS	3
6.1 Profile	3
6.2 Load Cell (pin)	3
6.3 Strain Gages	4
6.4 Accelerometers	4
6.5 Drop Dynamics	4
6.6 Model Performance (shell)	4
6.7 Model Performance (foam)	5
7.0 CONCLUSIONS	5
8.0 RECOMMENDATIONS	5
APPENDIX ONE - ACCELEROMETER DATA	26

LIST OF FIGURES

		Page
1.	Schematic of Proposed Container	7
2.	Drawing of Model	8
3.	Finished Model	9
4.	Shell	9
5.	Lid	10
6.	Gap Between Foam and Shell	10
7.	Foam Defect	11
8.	Location of Instruments and Measurements	12
9.	Profile Measurement Technique	13
10.	Drawing of pin	14
11.	Test Setup	15
12.	Profile of Shell After Drop 0 - 180 Degrees	16
13.	Profile of Shell After Drop 90 - 270 Degrees	17
14.	Deformation at Point of Impact	18
15.	Overall Deformation	18
16.	Pin Force - Time History 20 millisecond	19
17.	Pin Force - Time History 500 millisecond	20
18.	Deformation of Pin	21
19.	Pin Before and After Impact	22
20.	Strain Gage No. 2 Time History	23
21.	Strain Gage No. 3 Time History	24
22.	Foam Failure	25
23.	Foam Failure	25

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To Mr. H.N. Isaac
Manager
Nuclear Materials
Management Department
Design and Development Division

TRITIATED D20 TRANSPORT CONTAINER
COMPUTER MODEL VERIFICATION
PUNCH TEST No 1

1.0 INTRODUCTION

A program has been undertaken for the Nuclear Materials Management Department, to test the performance of an isocyanate foam filled sheet steel structure undergoing dynamic loading. The structure was designed to simulate the base of a proposed tritiated heavy water transport package. The structure was built to 1/4 scale dimensions.

The dynamic loading test closely simulated the IAEA specified drop onto a pin (reference 1). This punch test is a one meter drop onto a mild steel pin. The integrity of the containment and shielding must be retained after the test. Two samples were manufactured and one was tested at this time. The second will be tested when the results of the first have been fully examined.

2.0 PURPOSE

The purpose of this test was to provide experimental data on the behaviour of the structure under a dynamic pin drop test. The results from experimentation are to be used by the Nuclear Systems Department in their numerical simulation of the drop.

3.0 MODELS

The Models consisted of a 24 inch diameter outer shell made of 14 gage type 304 stainless steel and a lid made of 16 gage type 304 stainless steel. The outer shell modelled the base of the overpack, and the lid modelled the inner shell. The actual thickness of the bottom (outer shell) was 0.0730 inches and the actual thickness of the top (inner shell) was 0.0673 inches. All joints were TIG welded. The shells were filled with high density isocyanate foam which was later machined to a thickness

of 3 inches. The lid was then welded in place. There were also three lifting lugs attached. The model represented, at 1/4 scale, the base of the proposed tritiated heavy water transport container. The proposed container is shown in Figure 1. Figure 2 shows the drawing for the models and Figure 3 shows a finished model. The weight of the unloaded model which was tested was 49.6 lbs.

There were three problems encountered during manufacture of the models. First, the bottoms of the shells and lids were not flat after welding. On the sample which was tested, the bottom was initially concave. While no measurements were made on the lid, it was concave before the closure weld was performed. Figures 4 and 5 show the shell and lid. Because the distortion due to the punch was very large compared to the original concavity in the plate, the pre-test concave shape should have little effect on the results.

The second problem encountered was with the foam. There was shrinkage across the diameter of the foam resulting in a gap between the foam and the shell around the perimeter of about 0.08 inches or 0.67 percent. This may have been because of a high coefficient of thermal expansion and a high temperature at the time of setting, since the foam setting is a highly exothermic process. This shrinkage is believed to be related to the third problem and is discussed more fully below. Figure 6 shows the gap. Since most of the crushing and bending occurs within about three punch diameters, the shrinkage should have no effect on the results.

The third problem is believed to be due to thermally induced stress. When the foam was machined, a lens shaped disk broke out of the center of one of the samples. Figure 7 shows the defect. The crater which resulted was about 1 inch deep at the center and about 16 inches in diameter. It is hypothesized that this defect occurred because of non-uniform heating and cooling of the foam during setting. Since setting of the foam is highly exothermic, the center of the container would become much hotter then the outside. The center would also be set at a higher temperature than the edges. When the whole container once again came into equilibrium, the middle will have shrunk further than the outside. This would have resulted in a tensile stress in the center of the container and a compressive stress in the edge. The subsequent machining operation removed some material and upset the stress equilibrium resulting in a stress redistribution and material failure. Note that it was not this cracked sample which was tested this time.

4.0 INSTRUMENTS AND MEASUREMENTS

The model was instrumented with three accelerometers and three strain gages. Figure 7 shows the locations of the instruments. Measurements of surface profile were taken on the bottom of the sample across the diameter at two places 90 degrees apart, both before and after the drop test. In addition the same was done on the top of the lid after the drop only. Figure 9 shows the measurement technique. The reference bar was cemented to a surface at points where deformation, due to the drop, would be small. Figure 8 shows the location of measurements.

In addition the pin was instrumented with electrical resistance strain gages and calibrated as a load cell. All data was recorded on magnetic tape for post processing, and the event was recorded on video tape.

5.0 TESTS

As stated earlier, the test was designed to approximate the IAEA specified drop onto a pin test as outlined in Safety Series No. 6. The container with a concave bottom was weighted with 250 lbs of steel shot which was evenly distributed over the top of the lid. The weighted sample was dropped from a height of 1.2 m (48 inches) onto a 1/4 scale IAEA pin (Figure 10). It should be noted that this drop is less severe than the specified 1 m drop because less weight was used than that which corresponds to a true 1/4 scale - 1 m meter drop. For a true 1/4 scale - 1 m drop the total weight should have been 1/64 * 31,550 lbs = 493 lbs. This would produce an energy of 19,225 in-lb for a 1 m drop. The actual weight used was 300 lbs and the actual height was 48 inches producing an energy of 14,400 in-lb, which is low by about 35% for a true 1/4 scale test. The pin was fixed to a 12 inch by 12 inch by 2 inch thick steel plate which was anchored to a 30 inch cube of solid concrete. The concrete cube was resting on a strong floor. Figure 11 shows the test setup.

The model was later sawed in half and the foam was examined to determine the mode of deformation.

6.0 RESULTS

6.1 Profile

Figures 12 and 13 show the top and bottom profiles for the two cross-sections. Note that the bottom (base of the outer shell of the overpack) profile is corrected for initial shape and is therefore the absolute permanent deformation. Since initial profile measurements of the lid (base of inner shell) were not taken,

the actual shape is shown. Although the absolute amount of permanent deformation is not known, it is known that there was a significant amount because the accelerometer which was mounted at the center of the top plate with a threaded stud was knocked loose. The point of impact was deformed approximately 0.67 inches. The deformation extended from the point of impact out to the rim. If the top is assumed to have been flat initially, then the deformation at the center would be 0.48 inches. Figures 14 and 15 show the deformation.

6.2 Load Cell (Pin)

The impact force was measured by electrical resistance strain gages on the pin, (which had been calibrated for force). Time-force plots are shown in Figures 16 and 17. Note that two different scales are presented. The time of the entire event (initial impact) was approximately 17.3 milliseconds. The peak force of 23,000 lbs was reached in about 6.3 milliseconds.

The pin was also deformed plastically. Figure 18 shows the approximate deformation and Figure 19 shows a pin before and after impact. Damage to the pin consisted of slight peening of the edges.

6.3 Strain Gages:

The results from the strain gages on the bottom of the container are contained in Figures 20 and 21. Because of instrument failure, strain gage number 1 was not recorded. Peak strains from the other strain gages were out of range of the instrumentation, however the duration of the impact and permanent deformations were recorded. Gage 2 shows an event time of 17 milliseconds and a permanent deformation of 364 microstrain. Gage number 3 also showed an event time of 17 milliseconds and a permanent set of 191 microstrain. This shows that there was significant spring-back in the outer shell because the out-of-range value was 1100 microstrain. There was therefore at least 900 microstrain spring-back in the bottom shell. The permanent set in the pin was 6 microstrain.

6.4 Accelerometers:

Time histories of acceleration are contained in Appendix 1. Two time scales are presented to show the primary and secondary impacts. As can be seen, there is a 340 millisecond time span between the two impacts. The plots show mostly high frequency (1000 Hz) vibration with high peaks, up to 500 gs. These peaks occur because of structural resonances ie the impact excited resonant vibration modes in the structure. Accelerometer number 5 was extremely noisy because it was knocked loose from its mounting.

6.5 Drop Dynamics

The alignment was very successful. The model was dropped from a height of 48 inches onto a pin and the center of impact was 0.12 inches from its center. The video-tape showed that the model bounced about 3.5 inches and that a secondary impact occurred. The video also showed that the pin and the model were perpendicular when the impact occurred. Discounting the small amount of deformation of the pin, and considering the amount of bounce, it can be calculated that the container must have absorbed 93 percent of the energy.

6.6 Model Performance (shell)

The pin edge was virtually square (ie there was no radius machined on it). There was no shearing or tearing of the skin during this test which subjected the model to about 66% of the energy of a true 1/4 scale - 1 m drop test.

6.7 Model Performance (foam)

The model was subsequently sawed in half. The mode of deformation of the foam was found to be largely fracture with some crushing. The fracture was in the form of a wedge shaped section with a bottom diameter of about 4 pin diameters. The sides of the wedge started at an angle of about 45 degrees and ended parallel to the impact face. Figures 22 and 23 show the failure mode of the foam. Note that the sample was not broken all the way through the thickness. Also note that there were vertical cracks directly under the point of impact. These were due to bending and may have been started because of the hole which was machined for the accelerometer mounting stud.

7.0 CONCLUSIONS

1. The structural design of the container is very successful considering the amount of energy absorbed during this test, and the fact that integrity of the shielding and containment were maintained.

2. There was a high degree of spring-back in the shell and it did not fail from absorbing 66% of the energy of a true 1/4 scale - 1 m drop.

3. The model absorbed energy by plate bending and foam crushing and there was significant foam fracture.

4. There could be serious manufacturing problems because of the chemical and thermal properties of the foam.

8.0 RECOMMENDATIONS

The need to have a sample size greater than one is well recognized when experimental data is being collected. The second drop should be made using more strain gages, the correct mass for 1/4 scale, and if possible, the accelerometers should be embedded in the foam to measure the true dynamics of the model. This second drop will allow us to make any adjustments to the procedure which will be helpful in fine-tuning the model, and it will also ensure that any empirical relationships derived from the results are well founded.

A 1/4 scale prototype should be built and tested for two reasons. Firstly, methods of manufacturing must be tried and any problems due to thermal properties must be identified.

Secondly, a corner drop will be helpful for licensing. Since most of the equipment used in the punch test can be used for a corner drop test, it can be done for modest costs.

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REFERENCES

1. International Atomic Energy Agency, Safety Series No. 6, Regulations For The Safe Transport Of Radioactive Materials.

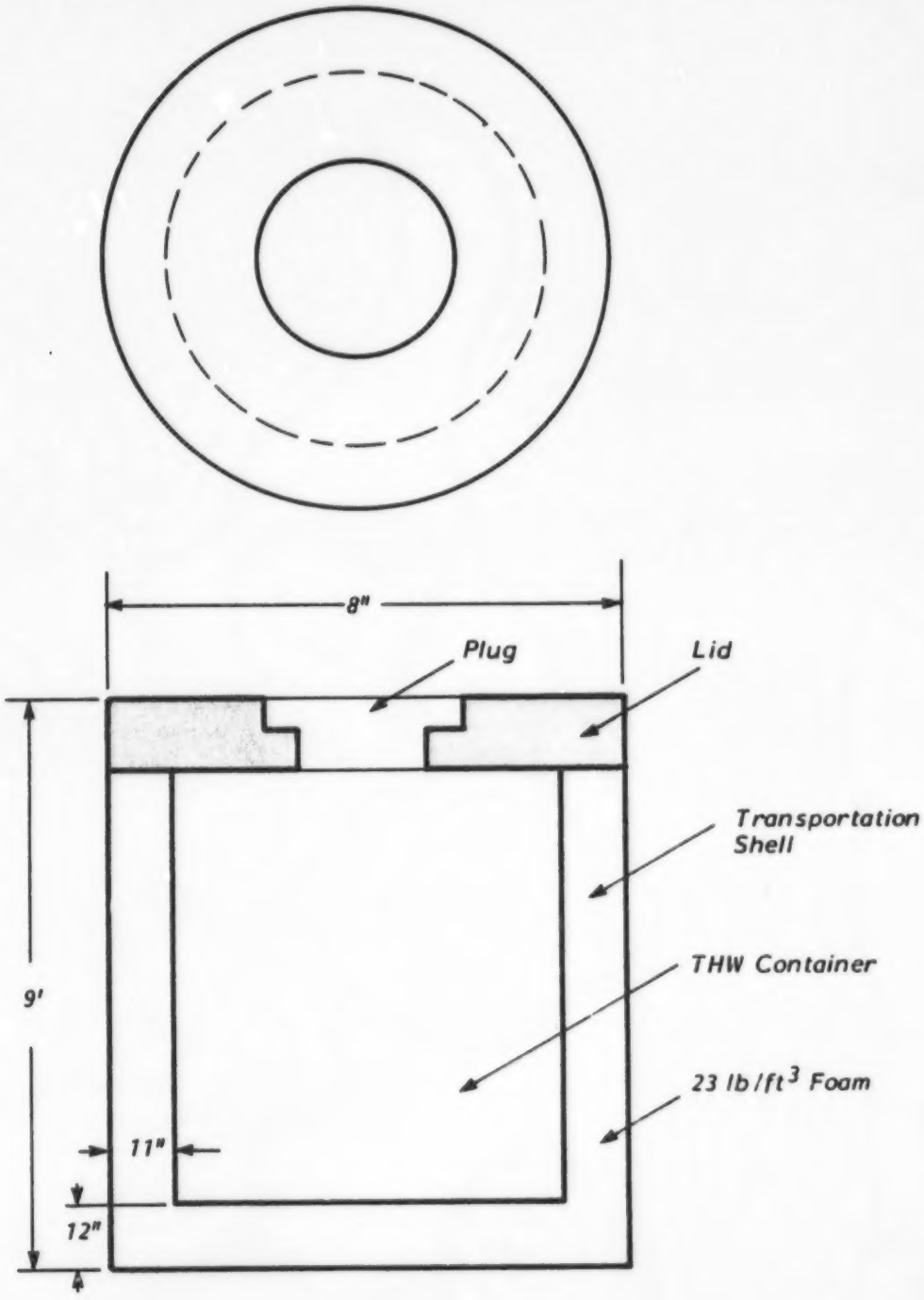

FIGURE 1

SCHEMATIC OF PROPOSED TRITIATED
HEAVY WATER TRANSPORTATION CONTAINER

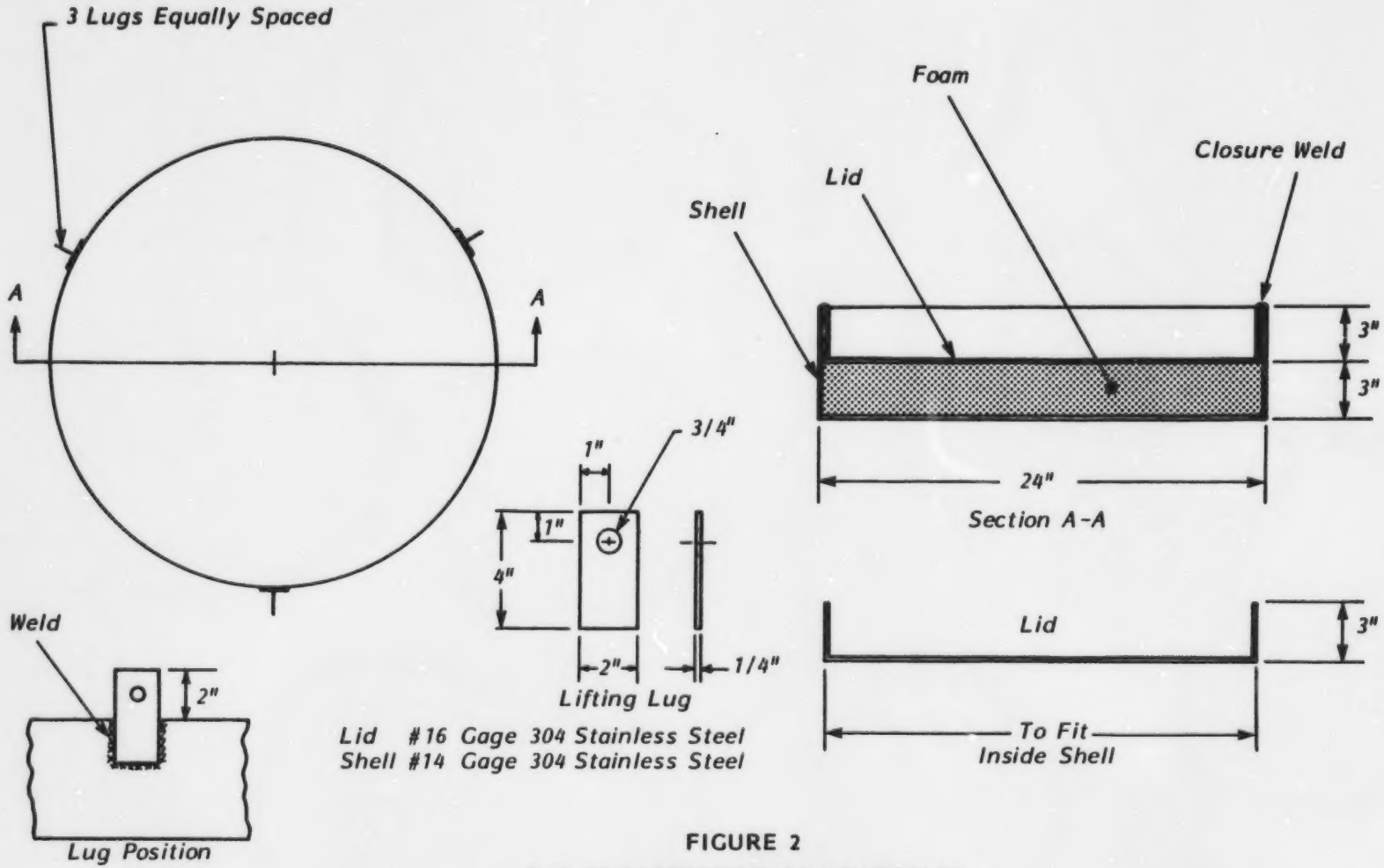

FIGURE 2

D_2O TRANSPORTATION CONTAINER
1/4 SCALE MODEL FOR PIN DROP

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166199 RD

Figure No 3 Finished Model

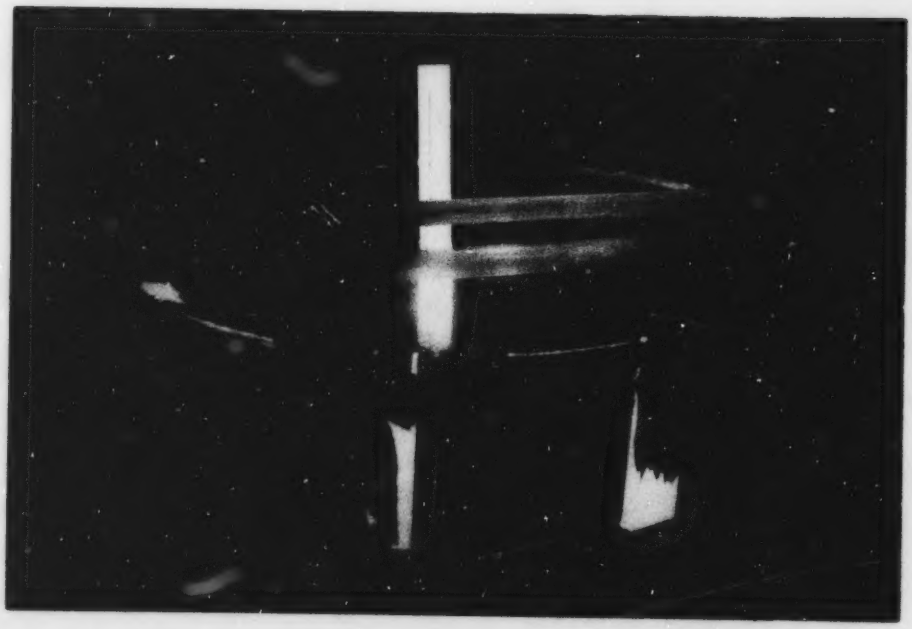

Figure No 4 Shell

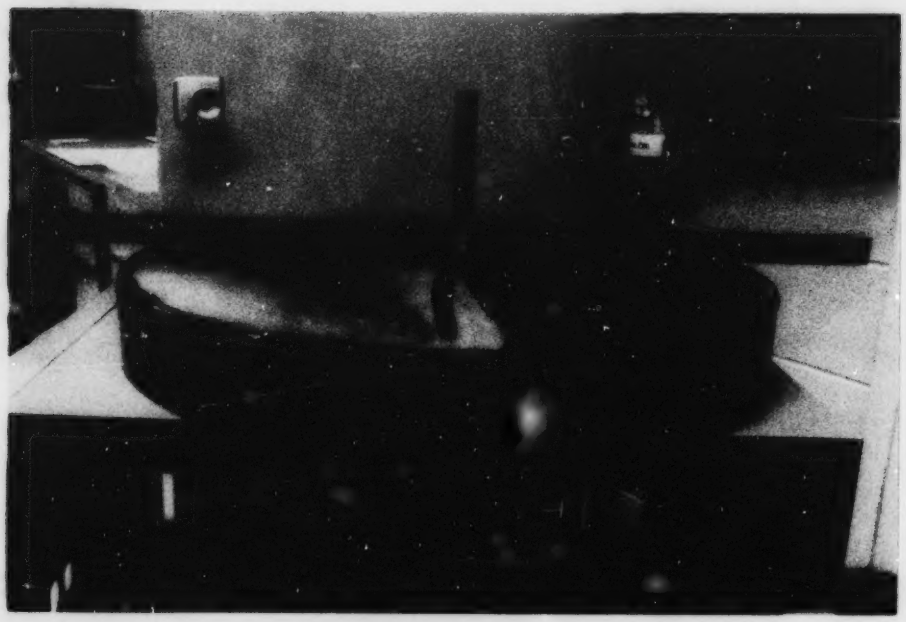

Figure No 5 Lid

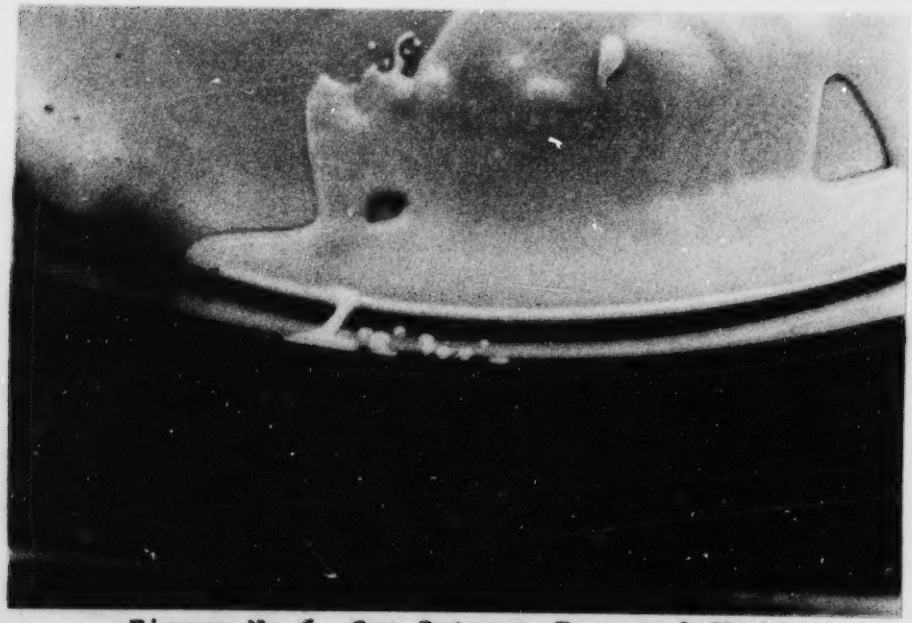

Figure No 6 Gap Between Foam and Shell

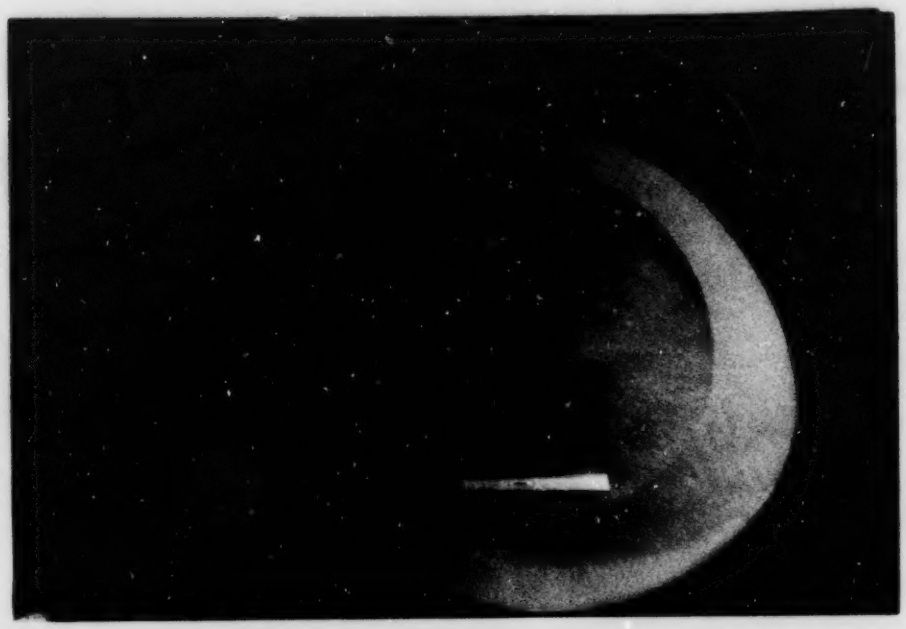

Figure No 7 Foam Defect

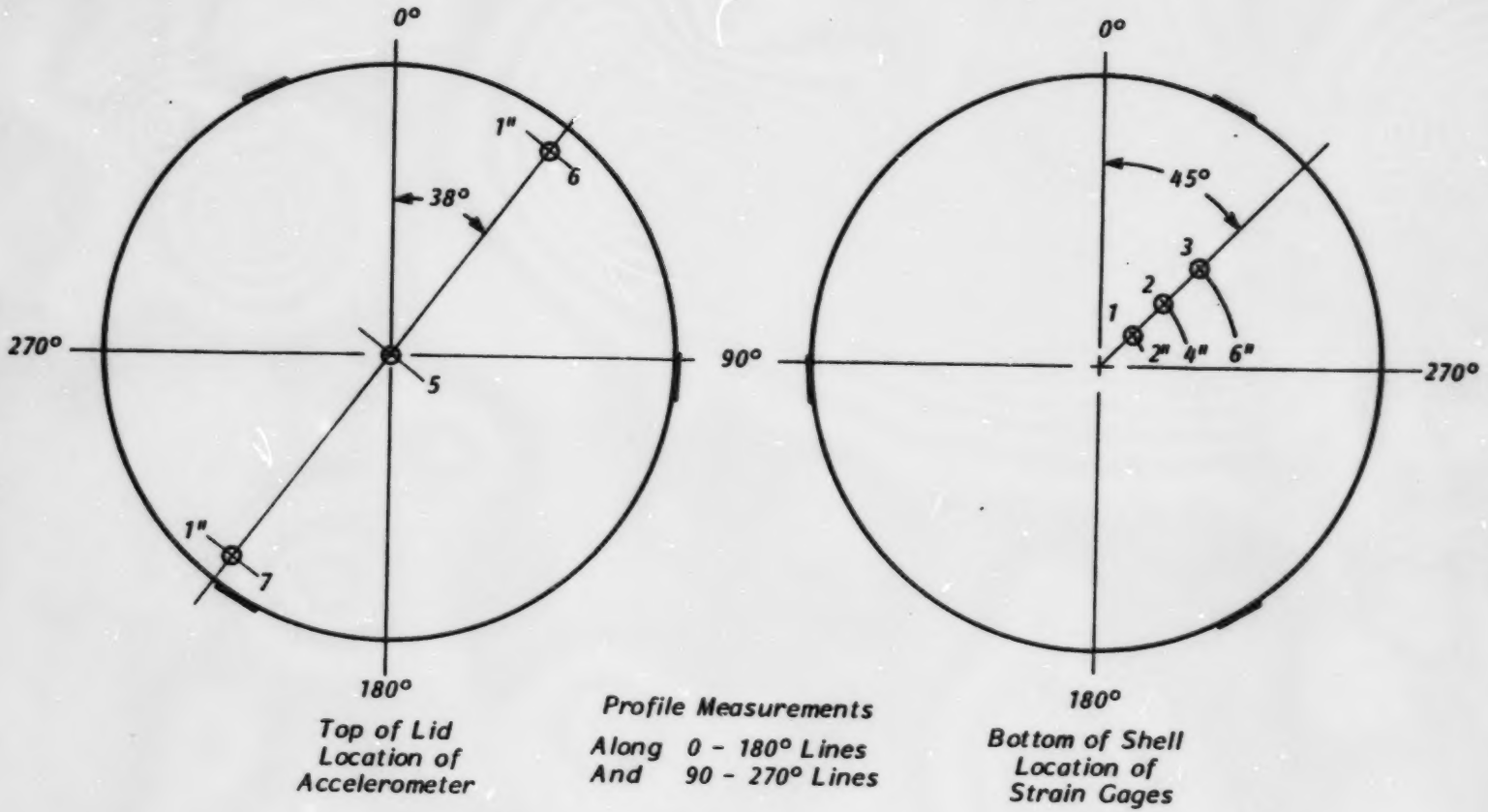

FIGURE 8
INSTRUMENT AND MEASUREMENT LOCATIONS

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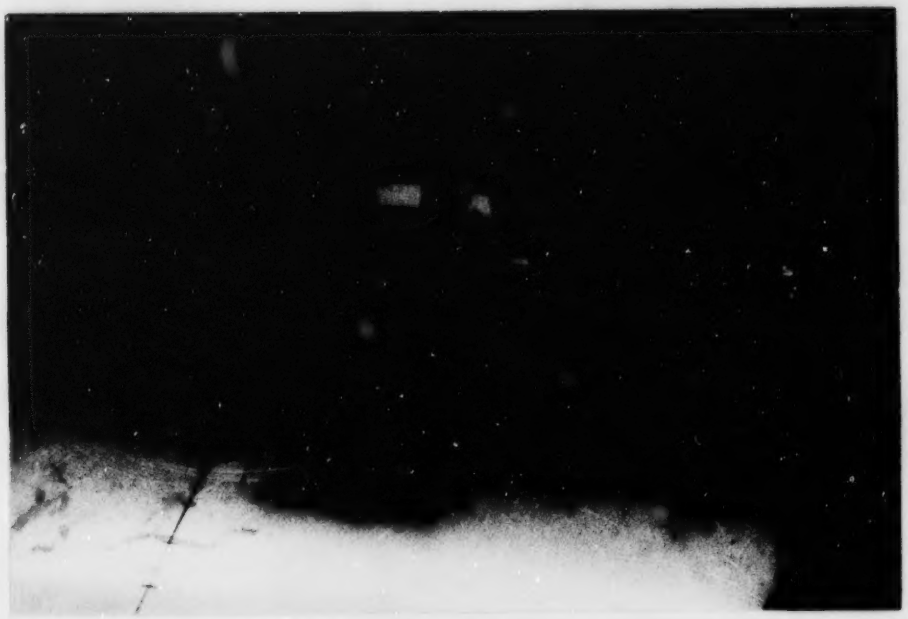

Figure No 9 Profile Measurement Technique

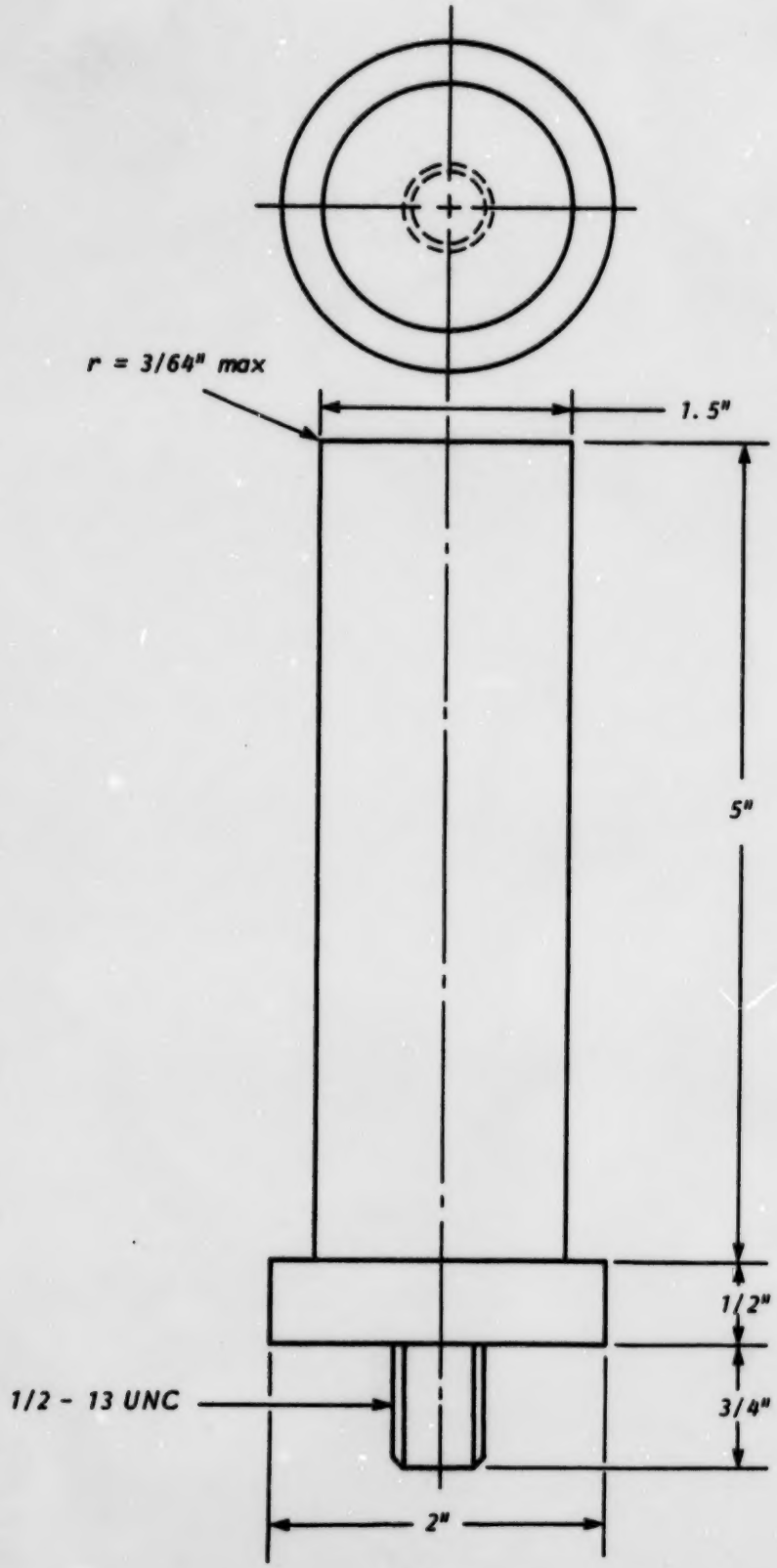

FIGURE 10
PIN DETAILS

Figure No 11 Test Setup

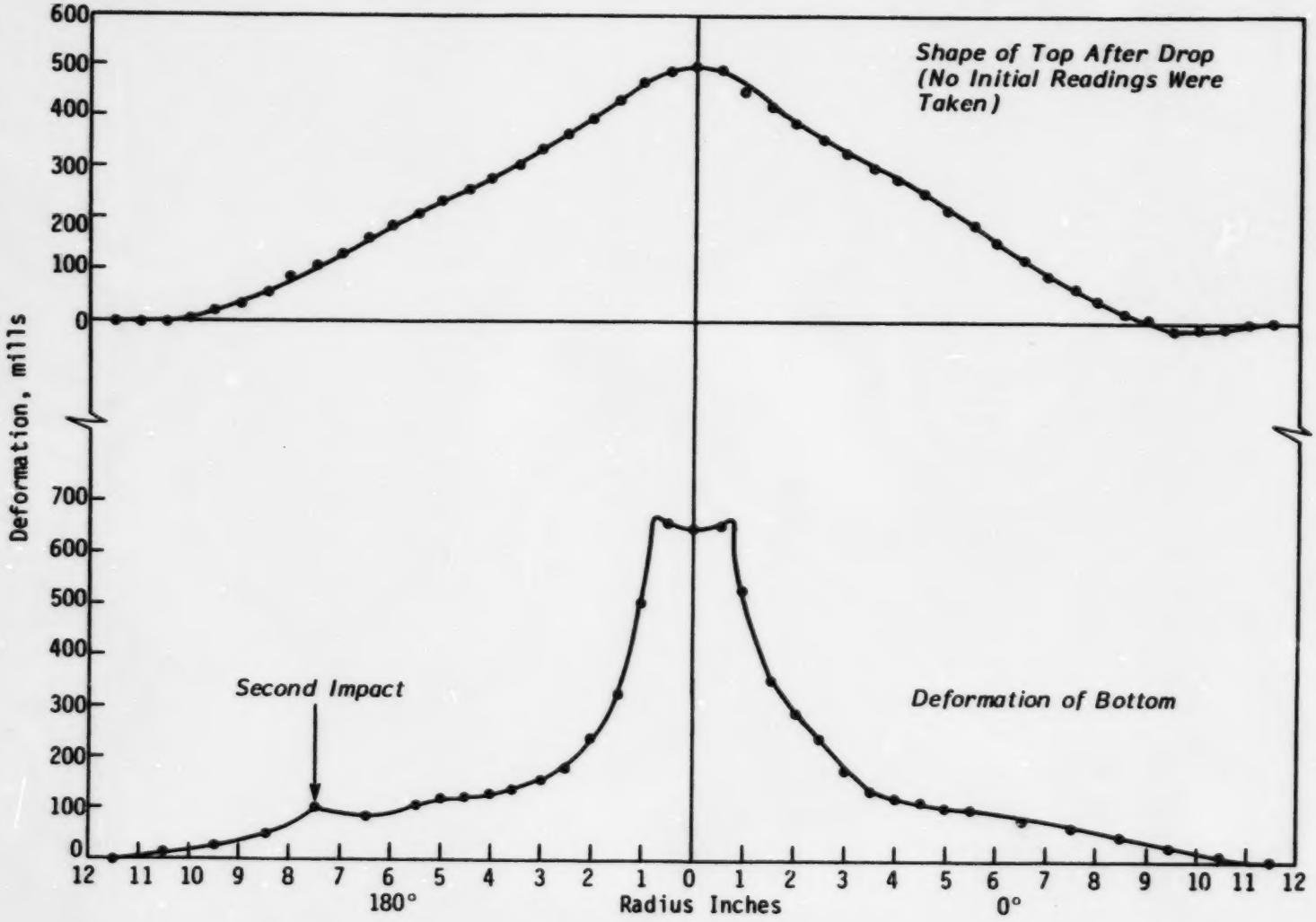

FIGURE 12

PROFILE ALONG 0 - 180° LINE

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166203 RD

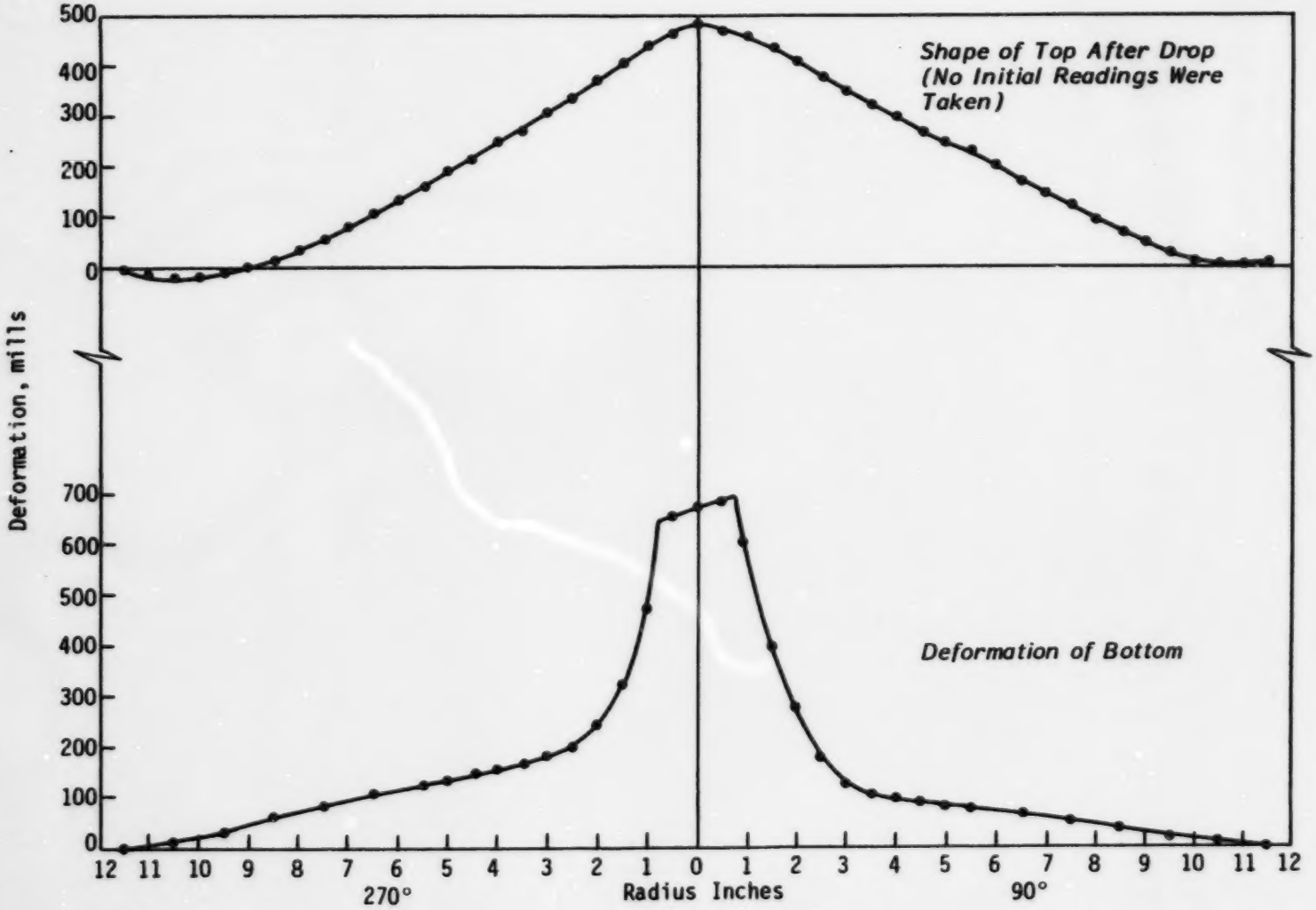

FIGURE 13

PROFILE ALONG 90 - 270 ° LINE

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166200 RD

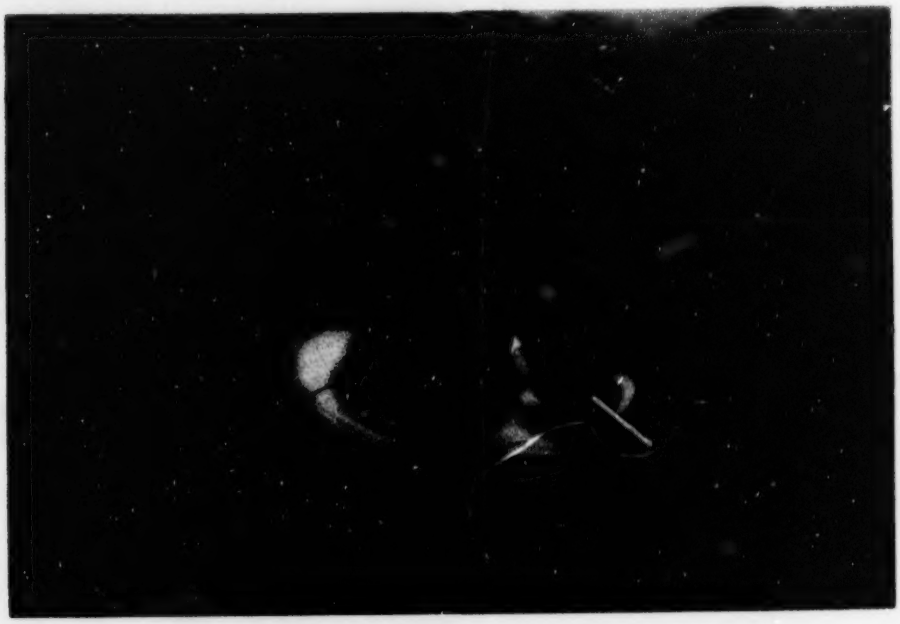


Figure No 14 Deformation at Point of Impact

Figure No 15 Overall Deformation

Figure 16

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984

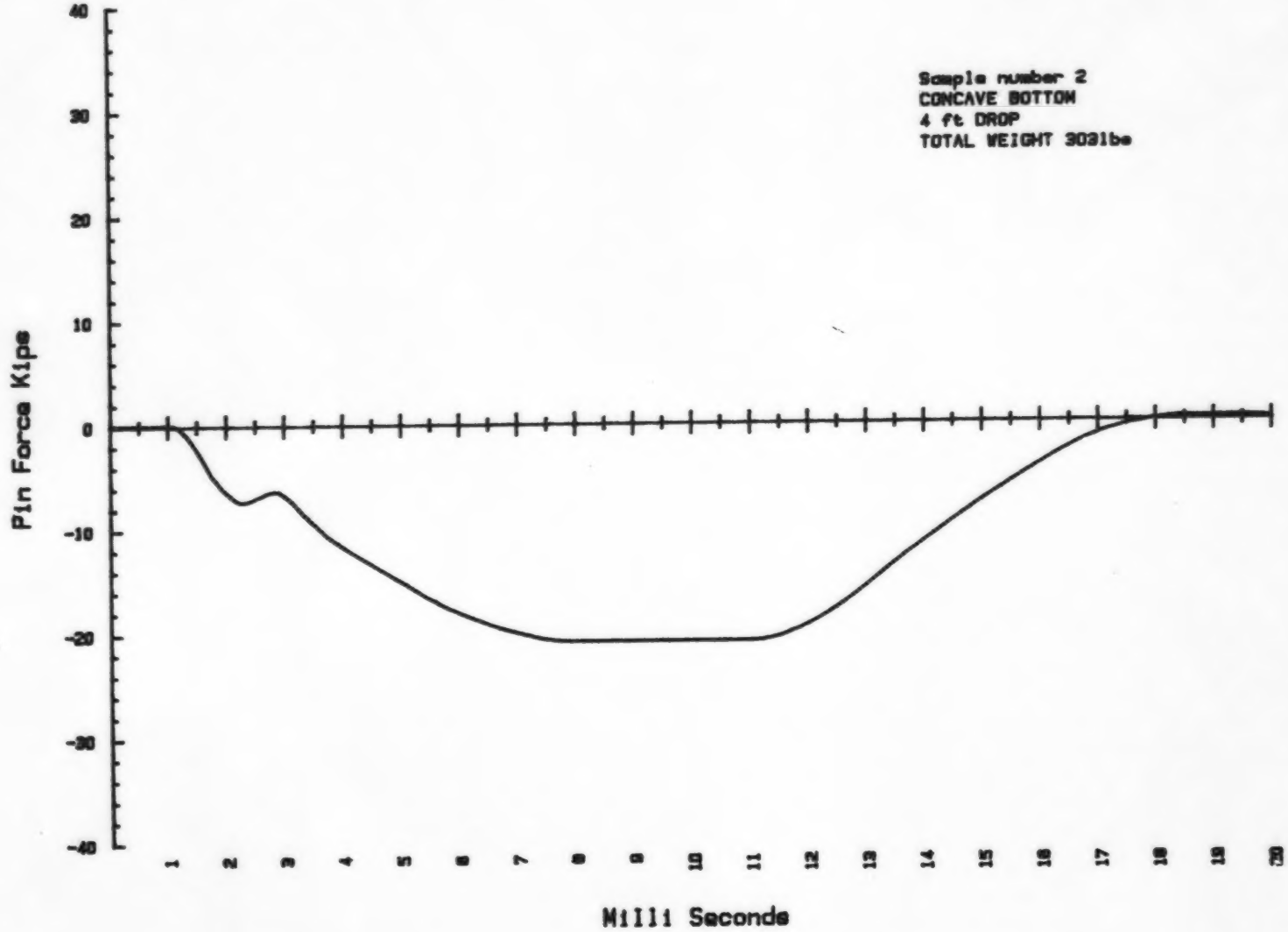
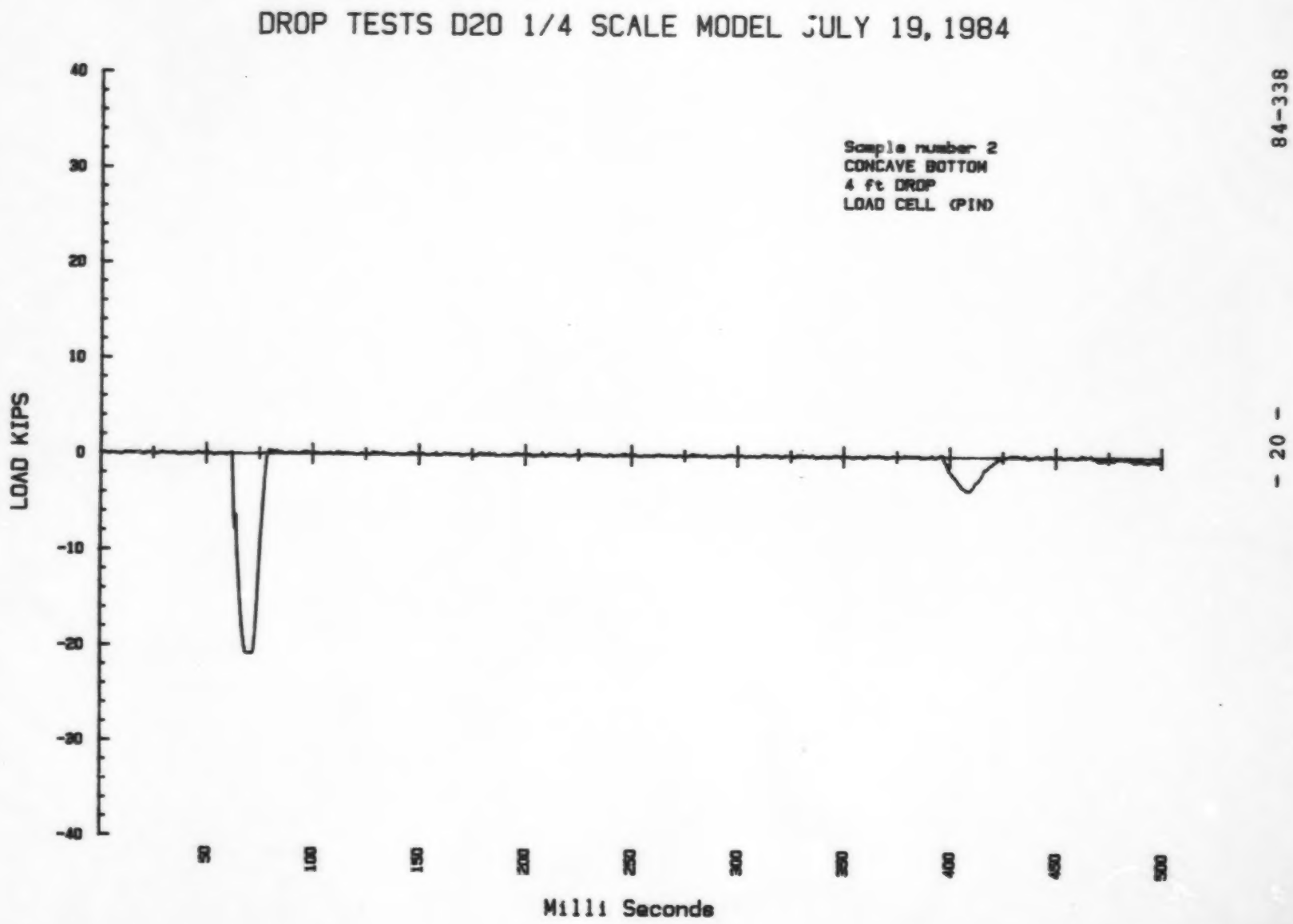
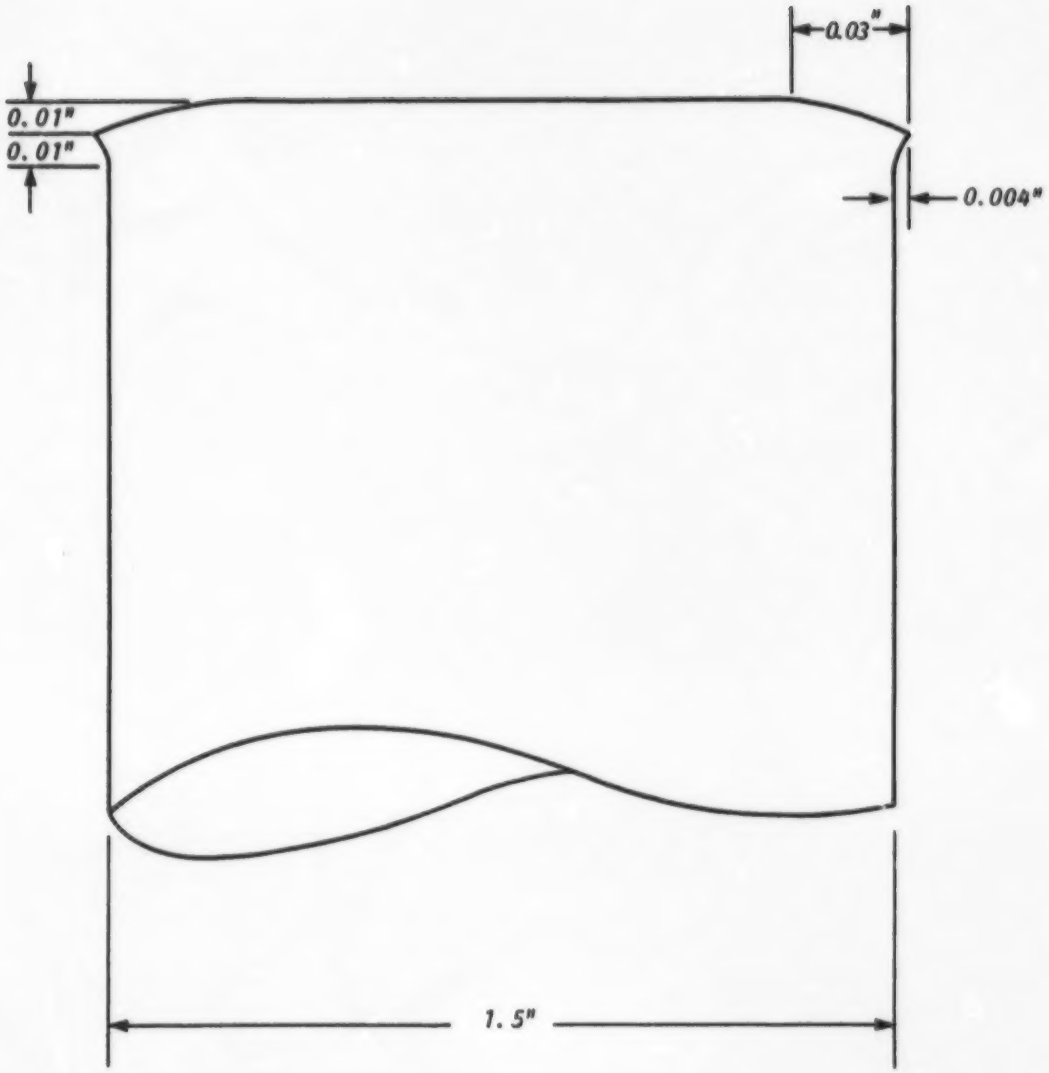


Figure 17


DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984
Sample number 2
CONCAVE BOTTOM
4 ft DROP
LOAD CELL PIND
84-338
- 20 -
LOAD KIPS
40
30
20
10
0
-10
-20
-30
-40
50
100
150
200
250
300
350
400
450
500
Milli Seconds



Not to Scale

FIGURE 18
PIN DEFORMATION

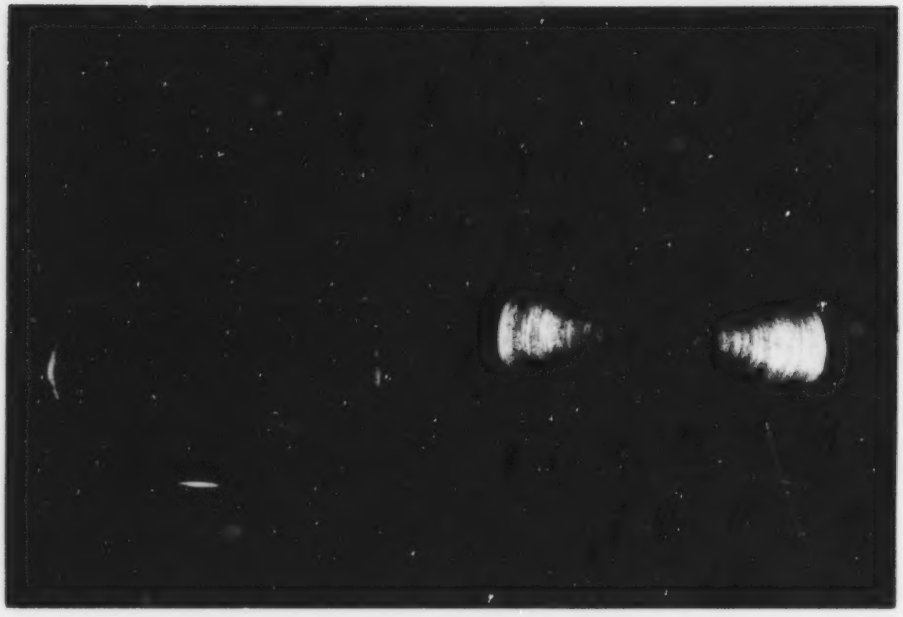


Figure No 19 Pin Before and After Impact

Figure 20

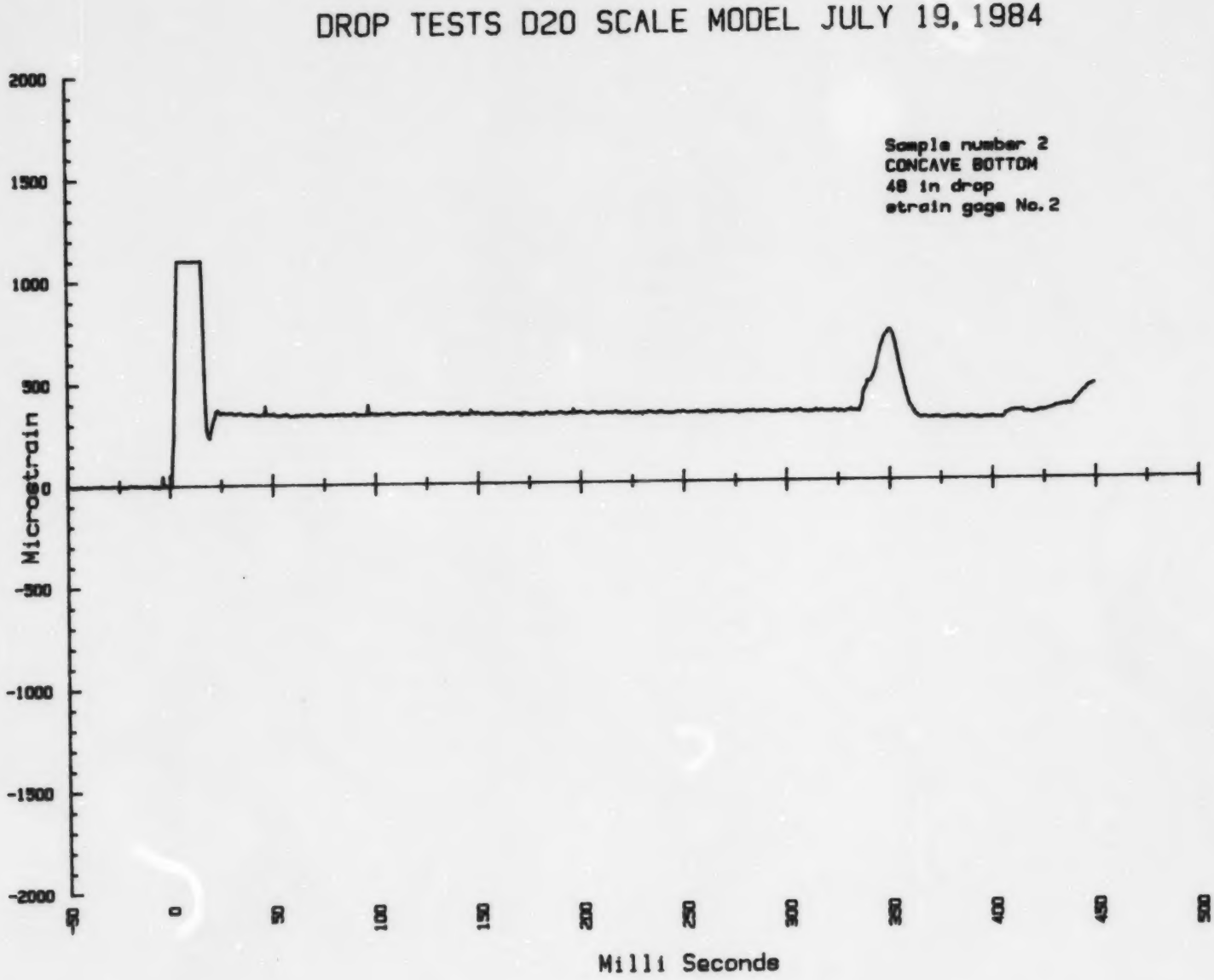

DROP TESTS D20 SCALE MODEL JULY 19, 1984
Sample number 2
CONCAVE BOTTOM
48 in drop
strain gage No. 2
Microstrain
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-50
0
50
100
150
200
250
300
350
400
450
500
Milli Seconds

Figure 21

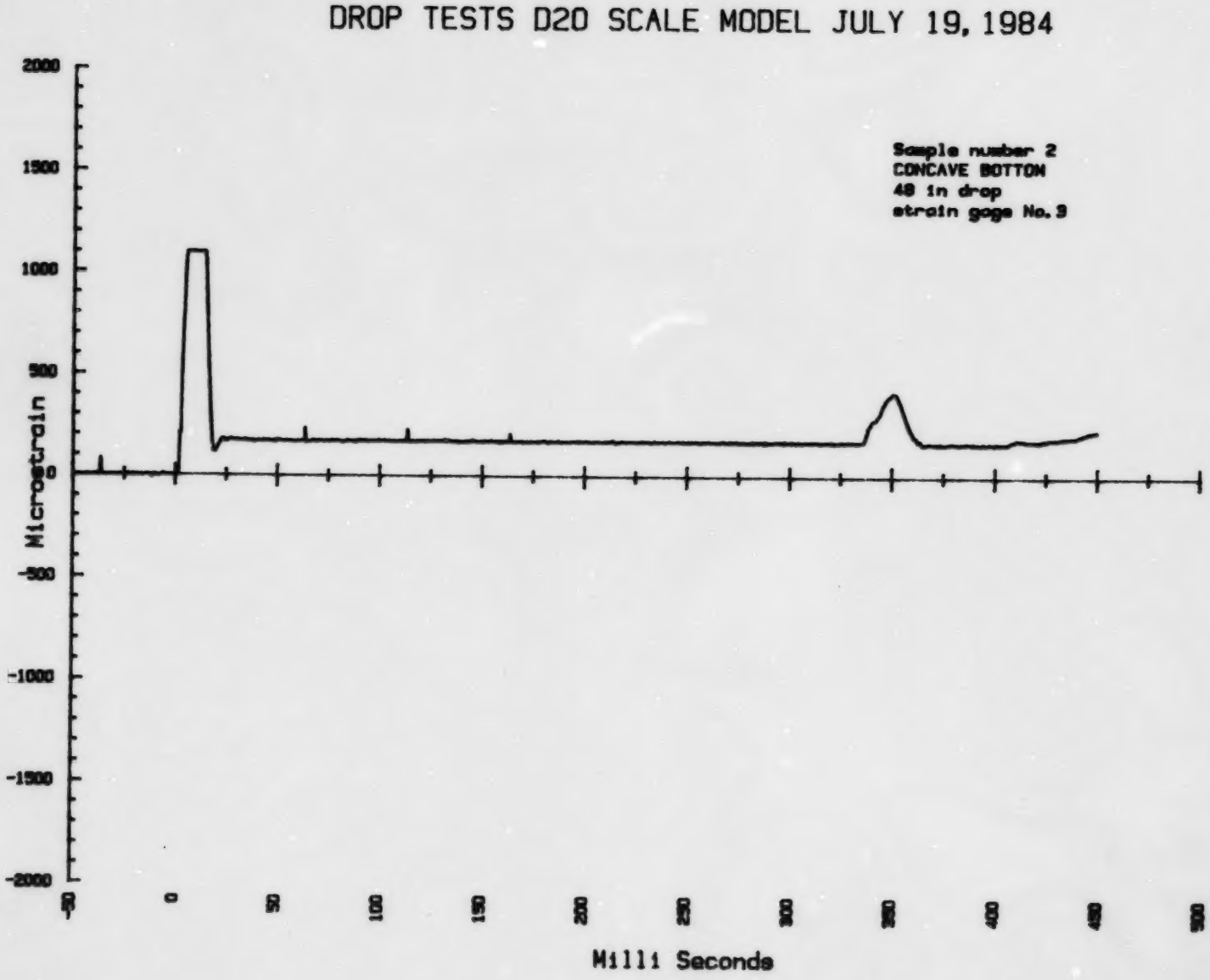


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Figure No 22 Foam Failure

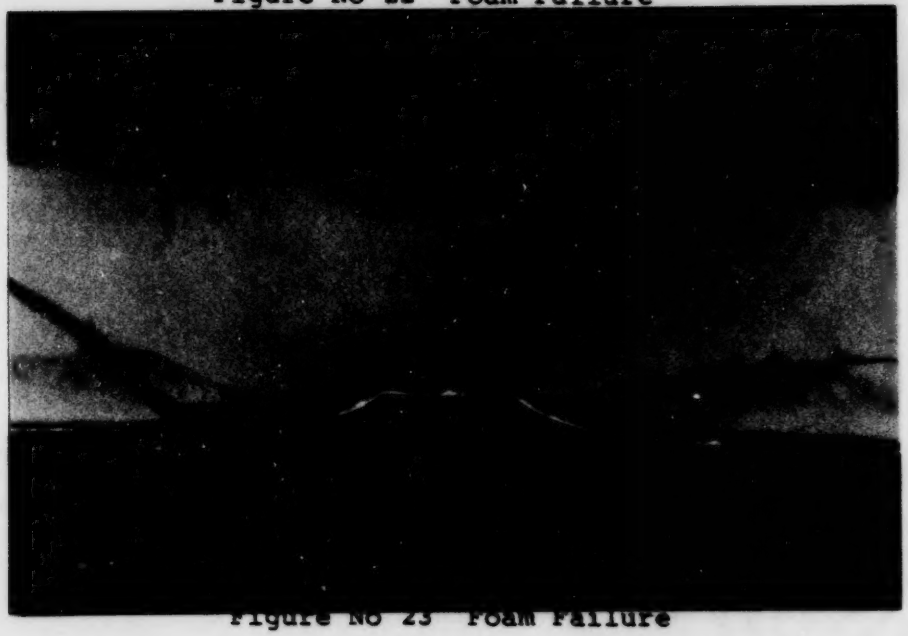


Figure No 23 Foam Failure

APPENDIX ONE

Acceleration Data

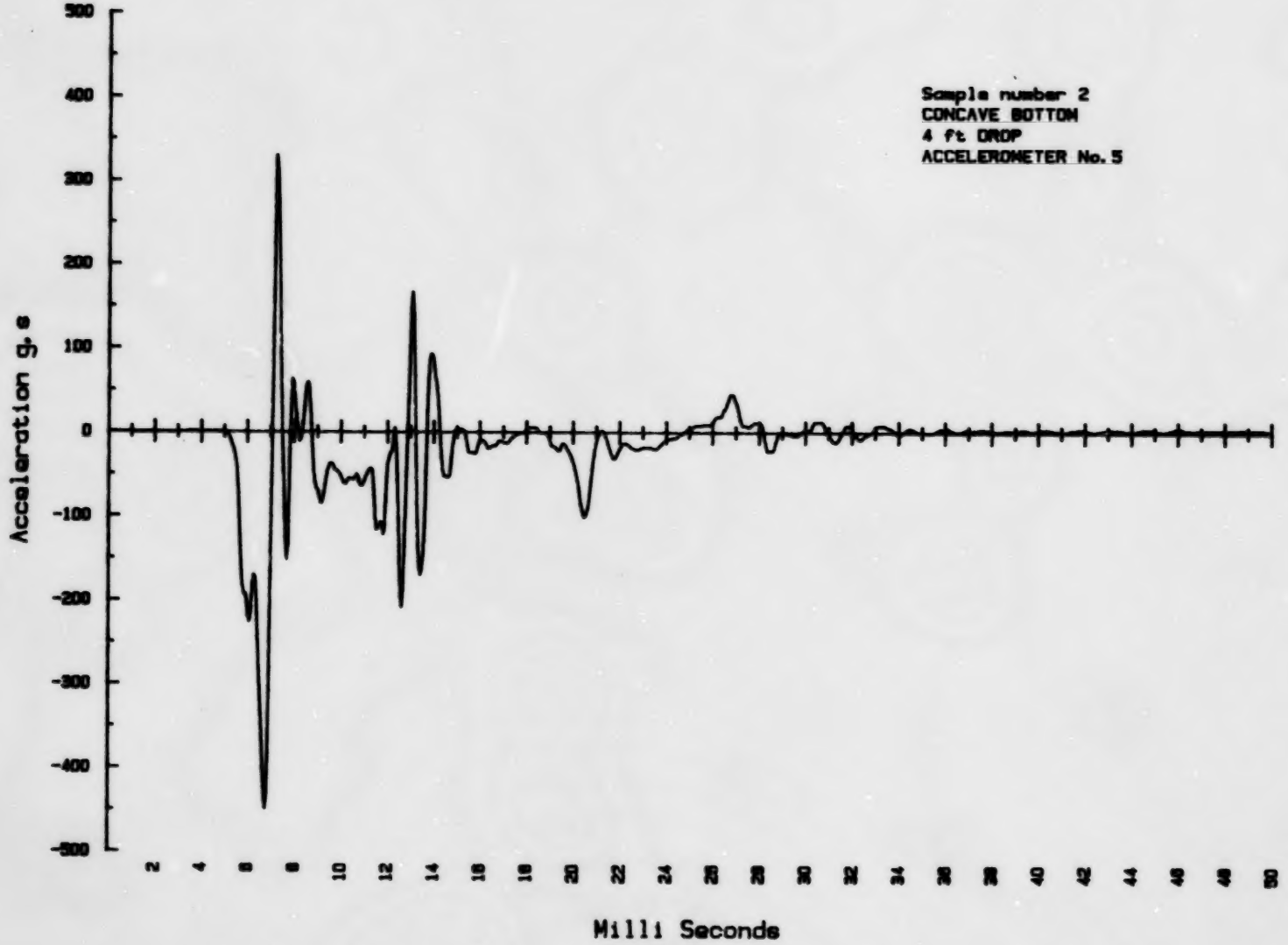
Time histories are contained in this appendix. The true dynamics of the model are hidden by the high frequency noise from local structural resonancies. Plots on two time scales are included for reference. Note that the shorter time scales indicate higher peaks. This is because both records contain the same number of points (1000). Because of this the longer time scale or slower digitizing rate will cause us to miss some of the peaks on the longer time scale. This is called aliases and is dependent on the speed of digitizing.

LIST OF FIGURES

1. Accelerometer No 5 - 50 millisecond plot
2. Accelerometer No 5 - 500 millisecond plot
3. Accelerometer No 6 - 50 millisecond plot
4. Accelerometer No 6 - 500 millisecond plot
5. Accelerometer No 7 - 50 millisecond plot
6. Accelerometer No 7 - 500 millisecond plot

Figure A1

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984



84-338

Figure A2

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984

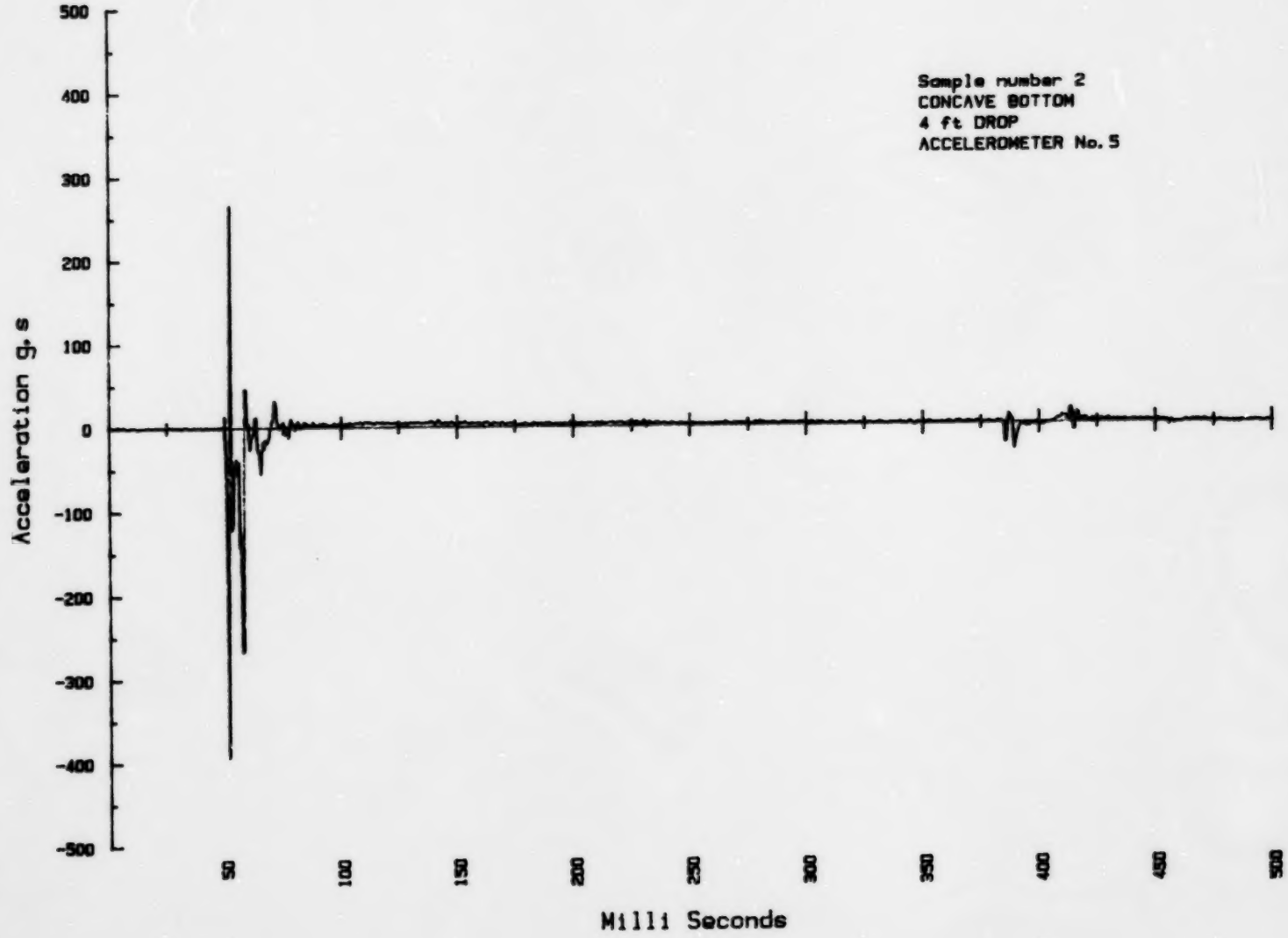


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Figure A3

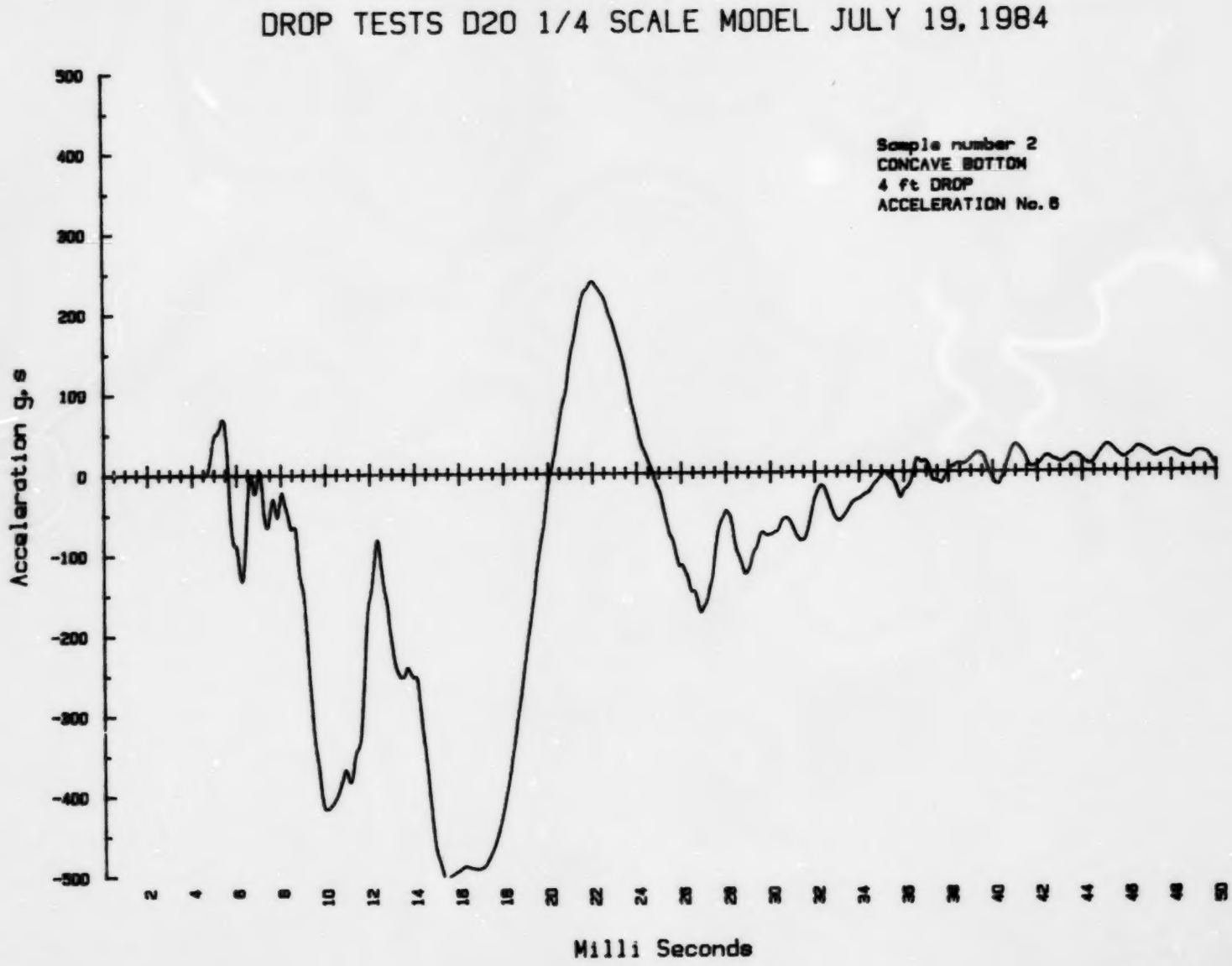
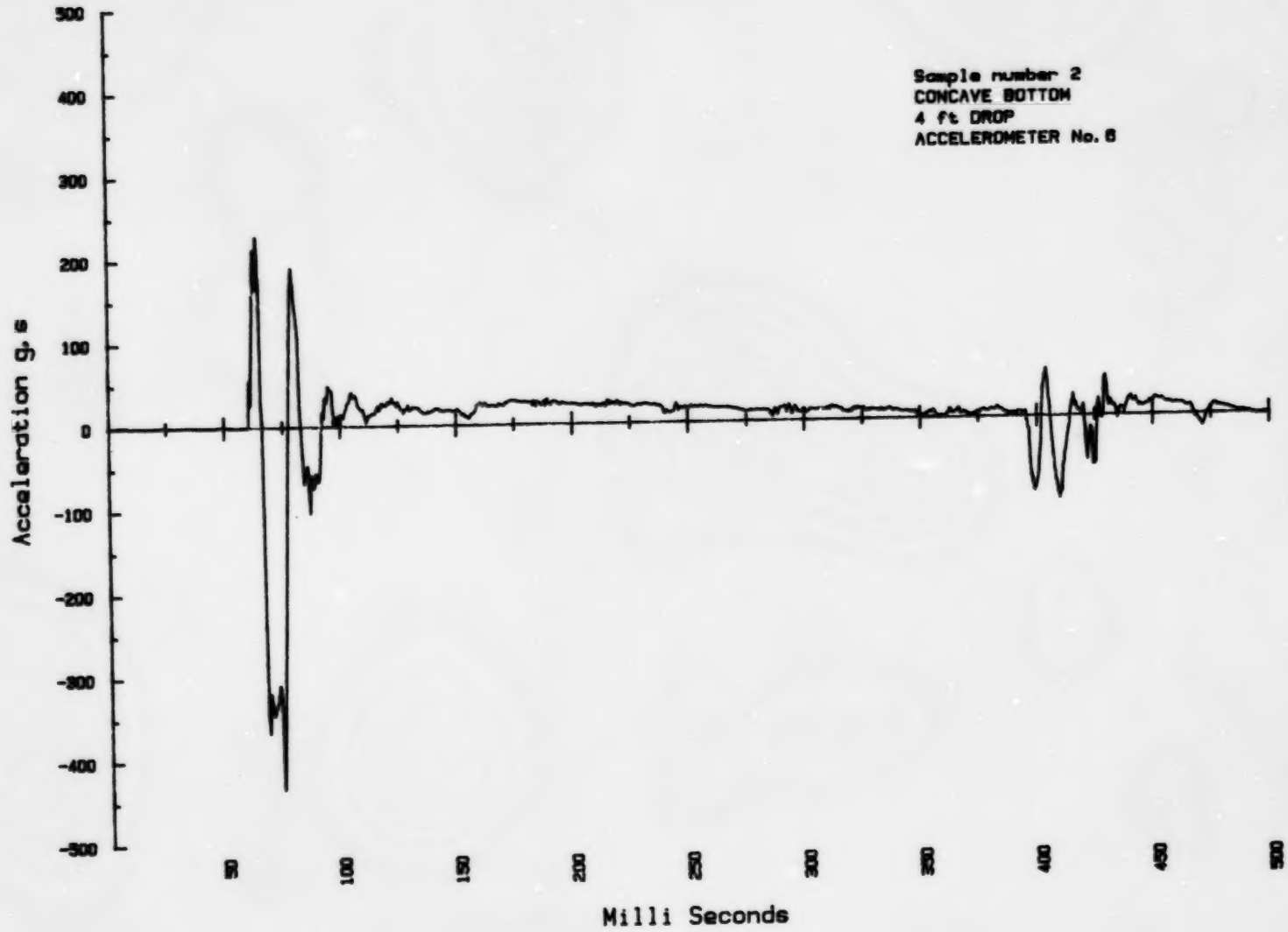

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984
Sample number 2
CONCAVE BOTTOM
4 ft DROP
ACCELERATION No. 6
84-338
- 30 -
Acceleration g's
500
400
300
200
100
0
-100
-200
-300
-400
-500
Milli Seconds

Figure A4

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984



84-338

Figure A5

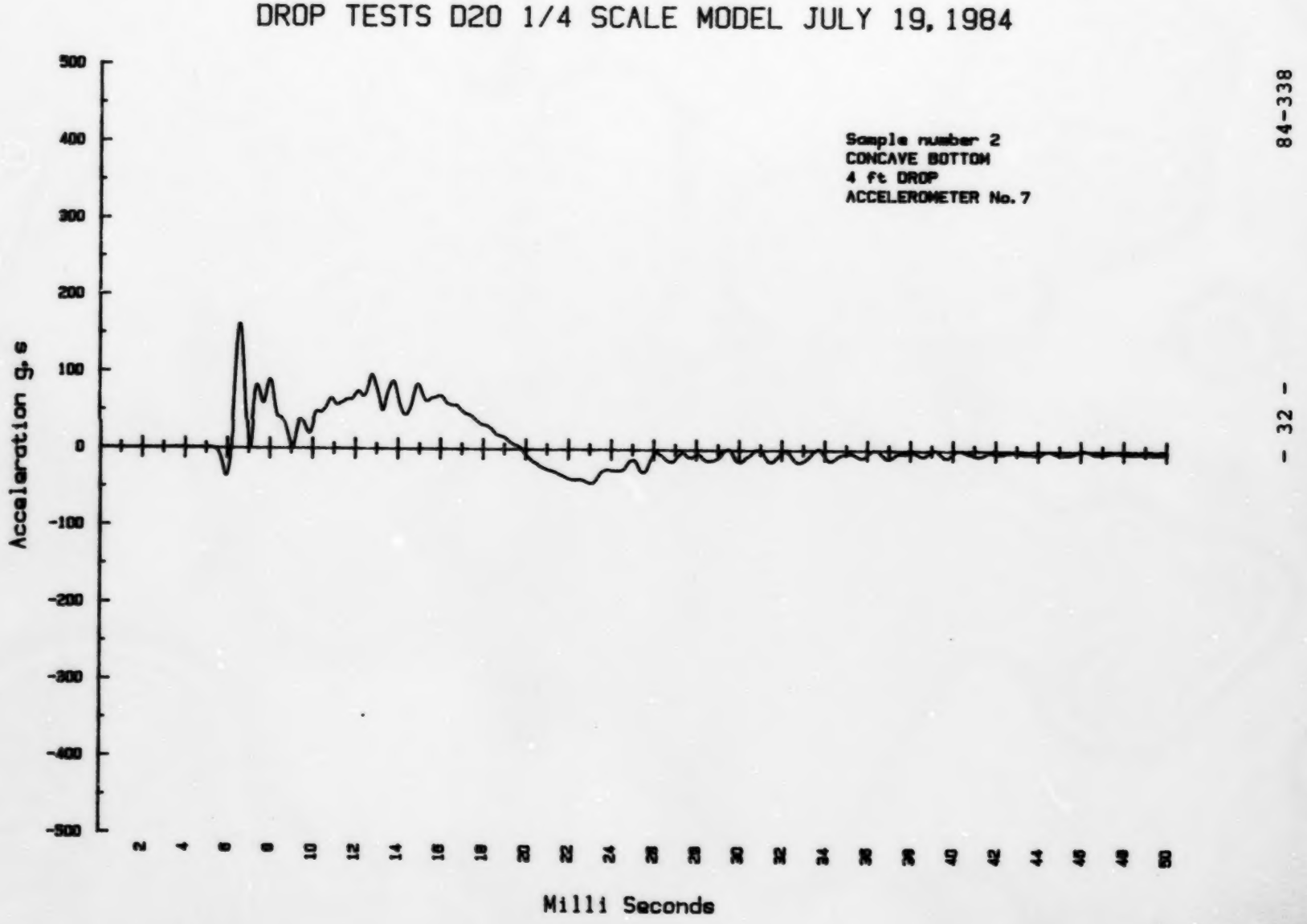

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984
Sample number 2
CONCAVE BOTTOM
4 ft DROP
ACCELEROMETER No. 7
84-338
- 32 -
Acceleration g.s
500
400
300
200
100
0
-100
-200
-300
-400
-500
Milli Seconds

Figure A6

DROP TESTS D20 1/4 SCALE MODEL JULY 19, 1984